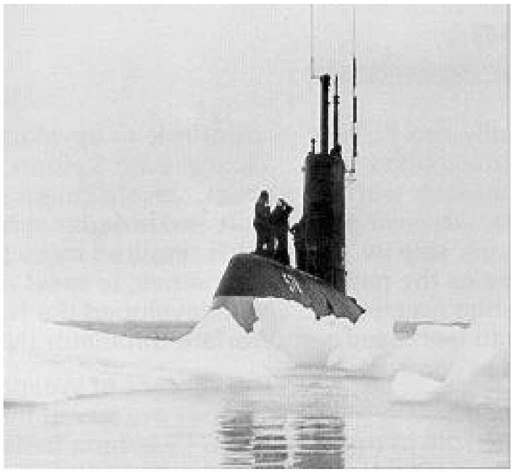
 

NEW TECHNOLOGY: THE NINTEEN FIFTIES

Introduction

Defense R&D basicallly had three partners: industry, universities, and DoD laboratories, each with a clearly defined role. Increasingly, industry played a larger role in military R&D because as the pace of technological change accelerated and the workload increased, the laboratories had to contract for more of their R&D products.

While "redefined," the role of the Navy laboratories in the 1950s changed little. The structure and management of the laboratories also remained much the same.

The bureaus continued to manage and sponsor NEL and NOTS throughout the 1950s. Direct management of each laboratory was shared by a military and a civilian manager, an arrangement still used today.

New technology changed the course of R&D at NEL and NOTS. The advent of nuclear-powered submarines required new methods for detecting and fighting submarines. Nuclear-powered submarines also made further arctic submarine operations possible; equipped with under-ice navigation equipment developed at NEL, U.S. submarines made significant under-ice passages. With the technical feasibility of a true multithreat warfare environment came a need for better methods of assessing incoming information; as an answer to that need, NEL played a major role in developing the Navy Tactical Data System (NTDS). Also, progressively longer ranged aircraft and broader surveillance fields required more sophisticated war games; to meet that challenge, NEL developed the Navy Electronic Warfare Simulator (NEWS).

The success of Weapon A in the postwar era paved the way for NOTS Pasadena to develop a rocket-assisted torpedo in the 1950s; in 1956, NOTS Pasadena began work on the Antisubmarine Rocket (ASROC), a rocket-propelled weapon capable of launching either a nuclear depth charge or a lightweight acoustic homing torpedo. When the Navy began work on the Polaris missile in 1956, NOTS Pasadena, with its unequaled experience in underwater ballistics, was called upon to develop the technology. Later, in 1958, NOTS Pasadena began development of the Mk 46 torpedo, which went on to become the principal lightweight torpedo for the United States and approximately 30 Allies.

Laboratory Management and Direction

The end of the Korean War in 1953 did not produce a decline in defense spending, which remained high at "Cold War" levels. Still, the new Eisenhower administration wanted to shrink government, including the military. Although a career soldier, President Eisenhower harbored serious reservations about the increased role of the military in peacetime America. He acted to halt the growth of government, including the military. On his retirement in 1961 he warned against the "military-industrial" complex. This concern naturally affected NEL and NOTS.

In 1955, President Eisenhower appointed the Commission on the Organization of the Executive Branch under former president Herbert Hoover. (The Commission was commonly known as the "Second Hoover Commission.") Its task force on research and development evaluated the military laboratories and endorsed the administration's attitude that the military should use universities for basic research and should involve industry as an integral part of design and development. The Second Hoover Commission evaluated both NEL and NOTS, praising them for the excellence of their facilities, technical staff, and leadership. They were "among the best of the military centers for research and development operations." The strength of these Navy laboratories, observed the Commission, was their ability to work within the military framework and to manage tightly focused programs on behalf of the services. Neither university laboratories nor private industry were as well equipped. Thus, in the view of the Second Hoover Commission, defense research had three partners: industry, universities, and DoD laboratories. Each had roles that it could perform best, and from this partnership would emerge an integrated and economical program of defense research and development.

Bureau Laboratories

Throughout the 1950s, NEL and NOTS were bureau laboratories, run directly by Navy material bureaus (BuShips and BuOrd, respectively). From 1946 until 1966, this pattern of sponsorship continued, with NOTS oriented toward BuOrd tasks: weaponry, guided missiles, underwater fire control systems, torpedoes, and the like. BuOrd was responsible for the design, purchase, issue, and maintenance of all guns, bombs, torpedoes, and rockets that the Navy used. Its R&D division assigned R&D tasks to various field activities; university laboratories, such as the Applied Physics Laboratory of Johns Hopkins University; contractors; and its own in-house laboratories, notably the Naval Ordnance Laboratory (NOL) then at the Washington Navy Yard and NOTS at Inyokern and Pasadena. The R&D division of BuOrd had eight separate product branches, two of which developed especially close relations with NOTS Pasadena: underwater ordnance and fire control.

Whereas BuOrd concerned itself with the Navy's armaments, BuShips involved itself with the design and construction of ships and their equipment. BuShips determined NEL's R&D agenda through funding specific projects in the application of electronics and in the application of related sciences to naval problems in the fields of acoustic and electromagnetic detection and location, communications, navigation, classification, identification, countermeasures, and signal and data processing.

Additionally, first NOTS and then NEL began to receive a grant for "foundational [i.e., basic science] research," which later became known as independent research. In 1959, the Navy formally established another funding category, exploratory development. Exploratory development money was allocated for the sort of practical problem-solving that the laboratories did best.

Growth and Specialization

Even though overall R&D expenditures increased, personnel ceilings and relatively low civil service pay scales made it difficult for the Navy laboratories to do everything on their own. As the pace of technological change accelerated, the laboratories had to contract for more of their R&D work, not simply for the production of the finished article whose prototype had been fabricated in-house. For example, NOTS Pasadena developed the Mk 46 torpedo beginning in 1958 with a contract with Aerojet General Corporation, also of Pasadena.

Similarly, Pasadena's Antisubmarine Rocket (ASROC) was developed with Minneapolis-Honeywell as prime contractor and NOTS Pasadena as technical direction agent. Under these arrangements, overall control remained with the R&D Division of BuOrd (the sponsor), but NOTS was responsible to the bureau for the performance of the new torpedo and its compatibility with related weapons systems. The trend increasingly was for the Navy to have the system prime contractor manage subcontracts, rather than have the laboratory manage a plethora of performers. The same pattern simultaneously developed in San Diego at NEL for projects such as the Navy Tactical Data System (NTDS).

The long-term result of these relationships and pressures was for the laboratories to develop a "cradle-to-grave" engineering responsibility with contractors whereby the laboratories designed, supervised the manufacture of, and then maintained a system throughout its lifespan. In practice, system development consisted of first "selling" a sponsor on a particular project (and on the laboratory's fitness to supervise its development), successfully following through on the R&D, overseeing the fabrication of prototypes, evaluating their performance, and then supervising training and field service maintenance, including periodic updates of the operational system. During the 1950s, NEL and NOTS Pasadena successfully directed the work of contractors and in-house research to produce a number of remarkable systems.

San Diego Management

NEL's Superintending Scientist, J. P. Maxfield, retired on 31 December 1954. His successor, Dr. Franz N.D. Kurie, received the title "Technical Director" (TD), which has since become standard throughout Navy laboratories. The TD acted as senior staff adviser to the CO. However, the most detailed supervision of the work underway at the laboratory came from BuShips project officers and civilian program managers in Washington.

San Diego Facilities

Despite the inclination of the Eisenhower administration to restrain defense spending, money and responsibilities continued to flow into the laboratories throughout the decade. NEL facilities expanded steadily throughout the 1950s. In 1951, the laboratory acquired the barracks area of Fort Rosecrans from the Army (until then the largest landowner on the Point). At the same time, NEL took over Batteries Woodward, Whistler, and Strong and began to convert them into usable structures.

In 1959, NEL was given local command and plant responsibilities for everything on the Fort Rosecrans Reservation. Thus, NEL became the landlord for an additional 577 acres and 134 structures.

Oceanographic Research Tower

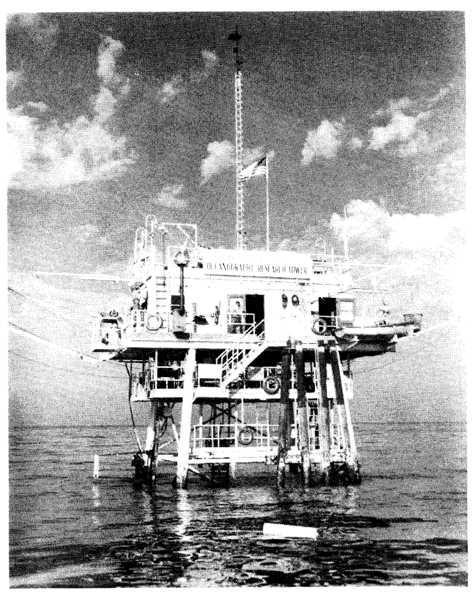
Neither a ship nor a shore installation by itself can provide the necessary conditions for the study of the ocean's shallow water and associated coastal marine environmental problems. Such research requires access to the open sea, stability, a fixed location, and a constant power supply. In 1959, NEL built an oceanographic research tower off Mission Beach to meet these requirements. Installed in 60 feet of water approximately 1 mile off Mission Beach, San Diego, the tower was easily accessible by regular NEL boat service, yet far enough from shore to provide a natural, open sea environment.

The tower's stability, based on slanting steel legs extending 63 feet into the ocean floor, assured continuous oceanographic and meteorological measurements from a fixed location. Versatile and adaptable, the tower could be used for equipment evaluation and for studies of the atmosphere, the shallow water environment, and the sea floor. Several investigations, related or isolated, could be conducted simultaneously.

Specially designed equipment supported research performed at the tower. The tower had track railings on three sides that could be used to raise and lower instrumentation to the ocean floor. NEL developed a 1-atmosphere, acrylic elevator to

Acrylic elevator at the Oceanographic Research Tower. The acrylic sphere accommodated an operator and one passenger for the descent through the 60-foot water column to the ocean floor.
Ron Reich (left) and Dr. William McLean (right).

Oceanographic Research Tower.

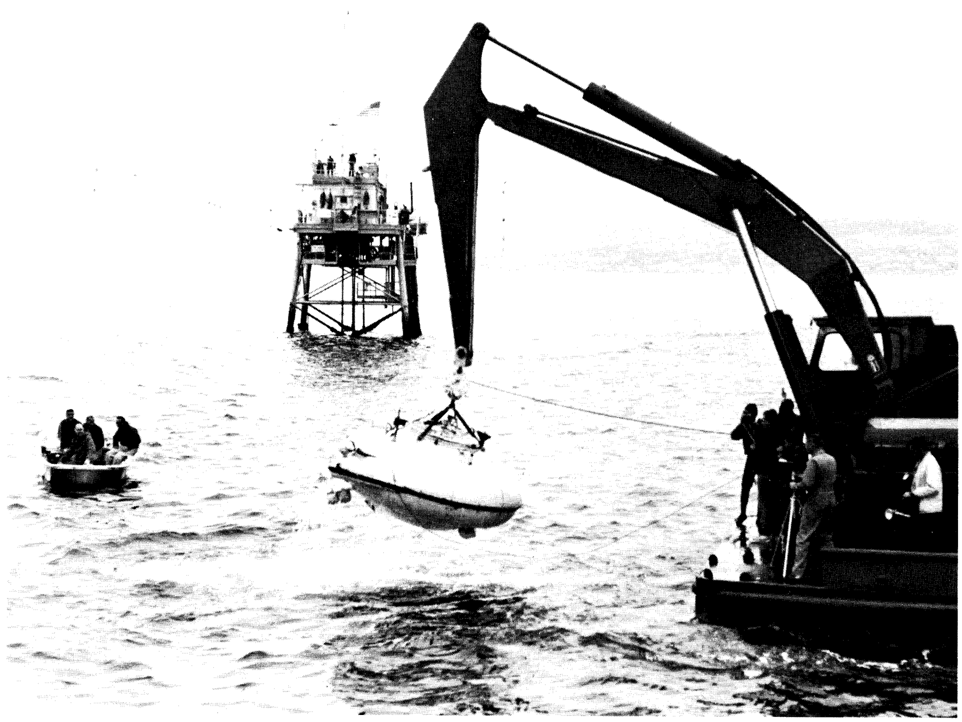


provide an observation chamber for biological and water-motion studies. The elevator "cage" was a transparent acrylic sphere accommodating an operator and one passenger for the descent through the 60-foot water column to the ocean floor. In the waters surrounding the tower, there were approximately 150 temperature sensors, waveheight sensors, and transducers hardwired to onboard instruments. Five arrays of thermistor beads continuously monitored the water thermal structure. Other equipment recorded dew point, wave motion, current speed and direction, sound velocity, and water clarity. A daily weather report, used by local authorities, originated at the tower.

Shallow-water oceanography studies predominated at the tower. Water movement throughout the entire water column was the most intensively studied variable at the tower, as it affected surface and subsurface navigation, acoustic transmission, and the permanence of equipment placed on the ocean floor. Acoustic studies centered on the propagation of subsurface sound signals, especially on the biological and physical factors that interfere with propagation, transmission, and reception. Other projects were related to electromagnetic wave propagation, marine chemistry, marine biology, marine geology, and materials research. A new research technique developed at NEL consisted of simultaneous investigations from the Cousteau diving saucer and from the tower. Joint studies included current speed and direction, water transparency, and temperature, as well as detailed studies of the sea floor.

Over the years, the laboratory's work at the tower abated, and the tower's usefulness diminished. In 1986, the tower was transferred to the Chief of Naval Research for management by the Scripps Institution of Oceanography. In January 1988, a storm razed the weatherworn and weakened structure. No plans exist to have it rebuilt.

Cousteau's Diving Saucer was used in coordination with the Oceanographic Research Tower.



NEL Tenant Activities

Personnel Research Unit

The year 1951 saw the establishment on Point Loma of the U.S. Navy Personnel Research Unit (today the Navy Personnel Research and Development Center—NPRDC). Originally, its mission was to support fleet training, education, and human resources planning, but over the years its work turned more toward psychology and human relations. In 1973, it became NPRDC, chartered to be the "principal Navy activity for conducting human resources RDT&E in the areas of manpower, personnel, education and training...and to stimulate human factors efforts in the design, development, and evaluation of new systems for operational use."

Visibility Laboratory

In 1952, the Navy moved its Visibility Laboratory from MIT to Point Loma, placing it under the Scripps Institution of Oceanography. The "Viz Lab" specialized in fundamental research on the transmission of visible light through the atmosphere and water. Its applied research focused on image formation and recognition, including camouflage. The "Viz Lab" today is a division of the Marine Physical Laboratory under the management of Scripps.

Health Research

In 1959, another Navy laboratory came to Point Loma—the Navy Medical Neuropsychiatric Research Unit, which was housed in the barracks area. Renamed in 1974, this laboratory is now called the Naval Health Research Center.

NEL: Expanding Research and Development

Navy Tactical Data System (NTDS)

NEL pioneered in automated command control by developing systems for every level of command from a single ship to the highest fleet command. NEL developed an operating model of a Coordinated Display System (CDS) that demonstrated the basic elements of an automated tactical data system for shipboard use. Previously, "tactical data systems" aboard Navy warships consisted of grease pencils, intercoms, and sound-powered phones. Shipboard weapons officers had to develop tracks manually by plotting contacts, trying to discern a pattern, and then determining which weapons system could best deal with the developing threat. The limitations of these methods had become apparent at the Battle of Okinawa in 1945 when the Japanese mixed conventional bombing runs with kamikazes—the latter offering a foretaste of missile warfare. By the mid-1950s, a true multithreat warfare environment became technically feasible where guided missiles, surface ships, submarines, and aircraft were all threats.

In April 1955, the Chief of Naval Research established a committee (the Lamplight Committee) on technical data-processing systems. In August of that year, the committee recommended a system based on a digital computer that would include a cathode-ray tube situation display, radio data links, and peripheral equipment. The system recommended would also be able to handle a full range of data-processing requirements for not only antiair warfare but for surface warfare, amphibious operations, electronic warfare, and ASW.

The Navy accepted these recommendations, and in 1956 the formal operational requirement for a Navy tactical data system was issued. As lead bureau, BuShips created a special projects office to oversee development of the initial system, called the Navy Tactical Data System (NTDS). Because the Navy's first choice, Bell Laboratories, did not think it could handle the entire project on its own, BuShips awarded prime contracts to three separate contractors in the spring of 1956: Sperry Rand's UNIVAC division (computers and system design engineering), Collins Radio (data communications links), and Hughes Aircraft (displays). NEL was tasked to do engineering and technical support for the entire program—assembling, testing, and evaluating every developmental model of all the equipment produced under the contracts. NEL also assisted each contractor with solving the technical problems that inevitably arose in the course of the NTDS project.

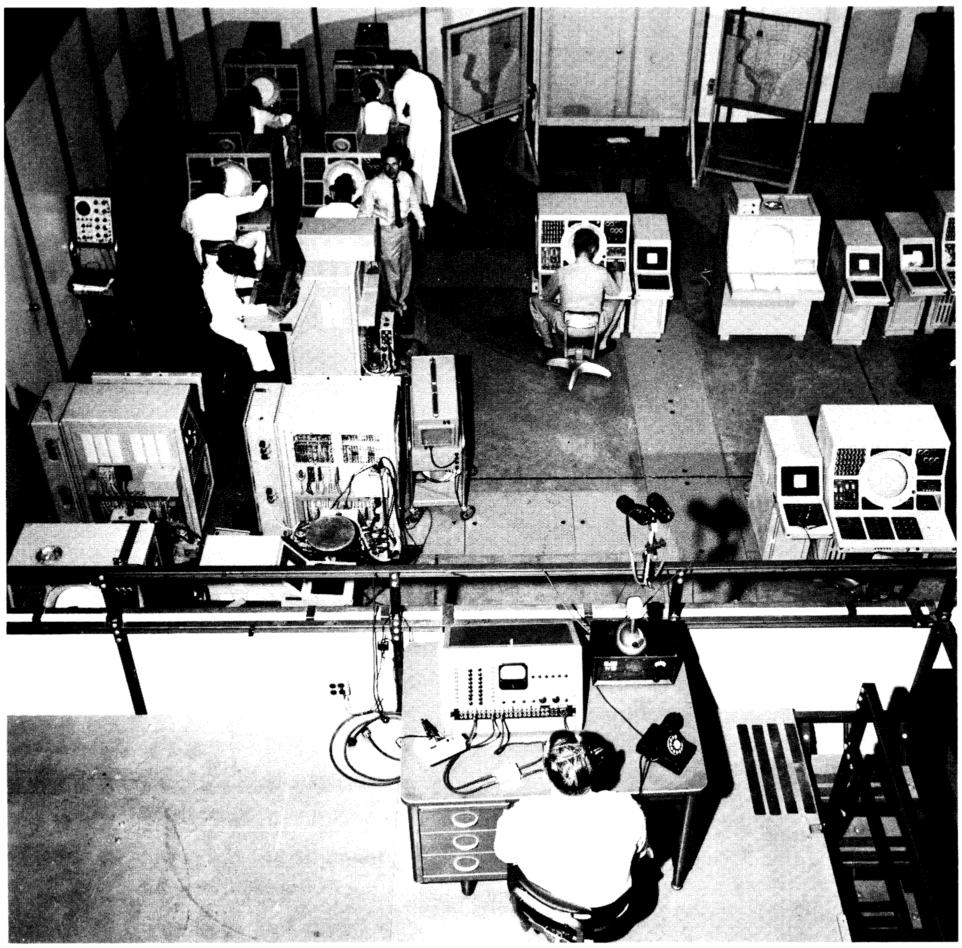
NTDS development required work that was new and not wholly accepted in the late 1950s: computer programming of realtime systems, development of computer algorithms, display technology, data transmission, and user/machine interface. NEL coordinated the entire effort, and the NTDS project at its peak employed 50 people: civil service engineers, Navy officers, and contractors on-site.

NTDS consisted of high-speed (for the time) computers, stored programs, specialized displays, and digital data links. The equipment was delivered to NEL in December 1958 for assembling and checkout. The first tests of the total NTDS system began in April 1959. NEL engineers wrote the technical evaluation procedures for the entire system and performed the technical evaluation (TECHEVAL). As lead laboratory, NEL also developed and tested both the advanced development model and the engineering development model along with the communications that made NTDS data available to other ships and aircraft.

NTDS enabled officers and seamen in a ship's Combat Information Center to establish and update tracks, determine their bearing and speed, and distribute information selectively to the relevant command or control displays. In time, with upgraded equipment and different programs, NTDS was adapted to provide automated data processing for ASW and surface warships. NTDS also offered ease of maintenance and in-service reliability. CNO approved it for service use in April 1963. Since then NTDS has had many incremental improvements, most of them engineered by NEL or NOSC.

NTDS proved to be a computing milestone. It validated the use of digital data processing and facilitated the Navy and the civilian world's shift from analog to digital data processing. The building-block concept employed in the NTDS design made it possible to configure the system for special applications and adapt it to changing requirements. Finally, NTDS exemplified the changed role of the laboratories. During World War II, UCDWR had developed hardware in-house. Only after its shops had fabricated a prototype was a contract put out to bid so a production version could be manufactured. In the face of high-technology warfare, the laboratories found themselves systems engineers for large projects involving major contractors and many subcontractors. In the 1960s and beyond, projects such as NTDS became the norm for NEL and its successor organizations—coooperative efforts between defense contractors and in-house laboratories.

NTDS training in full-scale mock-up of a shipboard Combat Information Center.



The Navy Electronic Warfare Simulator (NEWS)

The Naval War College at Newport, Rhode Island, has played regular war games since 1894. Games allowed officers a laboratory environment in which to act as commanders of ships, as commanders of squadrons or a fleet, and eventually as theater commanders. During the next 60 years, games became progressively more elaborate. Games were played first on tabletops, later on floors, with umpires monitoring the action and instructors critiquing the decision-making of players. Screens were used to replicate diminished visibility.

The advent of progressively longer ranged aircraft and broader surveillance fields led the College to consider an electronic board as early as 1945. In 1954, the War College asked NEL to develop an electronic war game. NEL began the project that year, and the result, the Navy Electronic Warfare Simulator (NEWS), was first used at the War College in May 1958. Developed before the microcomputer era, NEWS occupied three floors of the center wing of Sims Hall, the principal administration building at Newport. Commanders and staffs, up to 200 people, were housed in individual windowless rooms, each of which resembled the combat direction center of a ship or a flagship.

In a NEWS game, players were located in their own isolated command centers and provided with appropriate intelligence and typical communications from friendly forces. On a separate master-plot screen in the umpire area, the entire game was projected for the umpires, including not only position of units but also their combat effectiveness. A damage computer monitored the actions of all players and results of all combat, automatically reducing the weapons effectiveness and speed of damaged forces, and communicating own-force results to the player involved.

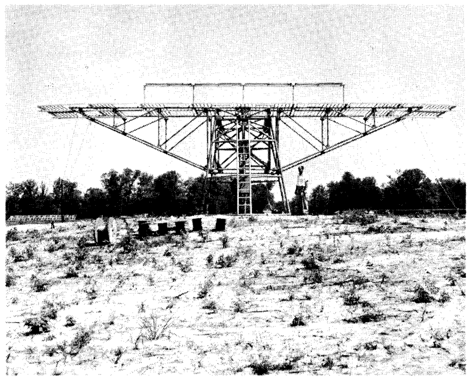
The umpires' summary plot of NEWS was a screen 15 feet in diameter on which images of simulated action were electronically portrayed. The umpires alone knew everything about the progress of a game: the position of all forces, the extent of damage to units, and the effectiveness of remaining forces. The players, however, as in real combat, got only bits of information. They might become aware that their own ship had been hit, had lost speed, was on fire, or could no longer maneuver, but they did not know for certain the location of their opponents or how much damage had been inflicted.

Navigation

NEL developed a low-frequency (LF) radio navigation system from 1950 to 1957. Known as Radux, the system (first tested in 1954) demonstrated for the first time the extreme phase stability of LF signals. Radux-equipped ships or aircraft, triangulating on three LF signals emanating from known shore positions, could determine their position to within 2 nautical miles—a remarkably accurate position compared with celestial navigation. The three synchronized Radux sites were in Hawaii, San Diego, and Bainbridge Island, Washington. Together, they covered the Northern Pacific.

Satellite Tracking

NEL established the first West Coast satellite tracking station in 1957, planned in cooperation with the Naval Research Laboratory (NRL) for the International Geophysical Year during 1957 and 1958. As it turned out, the Minitrack Station at Brown Field, California, was completed in October 1957 just ahead of the Russian Sputnik. The station, because of its location, was the first non-Soviet satellite tracking station to confirm that the Sputnik had orbited the earth. Built for Project Vanguard (the Navy's entry in the satellite program), the Brown Field station tracked Sputniks I and II and Vanguard satellites in the late 1950s. Linked by teletype to NRL, the Brown Field station fed tracking data directly to the computers in Washington.



Minitrack Station, Brown Field, CA. The Brown Field Station tracked Sputniks I and II and Vanguard satellites in the late 1950s.

Continuing Arctic Research

During the 1950s, the "fantasy" of arctic submarine operations became a reality. At the end of the decade, USS *Skate* (SSN 578) surfaced at the North Pole, dramatic evidence of the Navy's ability to go anywhere. The key technological breakthrough that made this possible was the development of the nuclear-powered submarine, which unlike air-breathing diesel-electric submarines, could remain submerged throughout lengthy transpolar cruises. It is doubtful, however, whether the Navy would have risked its new nuclear submarines had not the techniques for under-ice navigation been developed over a period of years under the direction of NEL.

In 1952, USS *Redfish* (SS 395), guided by Dr. Lyon, went 20 miles into the ice pack and remained submerged for a record 9 hours, giving a tremendous boost to advocates of arctic submarine activities.

But not until the late 1950s did a submarine capable of remaining beneath the ice canopy exist: the nuclear-powered USS *Nautilus* (SSN 571). In the summer of 1957,

Nautilus was tasked to sail beneath the polar ice prior to a NATO exercise in September 1957. As usual, Dr. Lyon was onboard the submarine when it left New London on 19 August 1957. Its mission was to penetrate to 50 or 60 miles and then return. The submarine did better, actually getting within 180 miles of the North Pole before returning. *Nautilus* covered nearly 1000 miles and remained submerged for 74 hours.

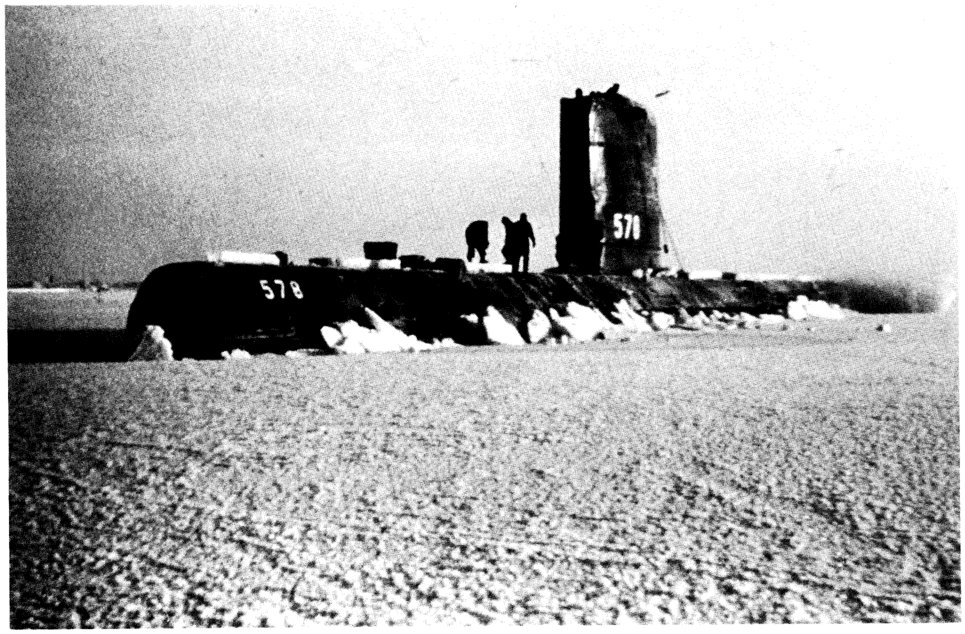
The success of *Nautilus* in making the first underwater passage into the Arctic Ocean led the Navy to plan a much more ambitious exercise for the summer of 1958—a submerged voyage from the Pacific to the Atlantic. After a winter of planning, *Nautilus* passed under the North Pole on 3 August 1958. To a nation still smarting from Sputnik, this success by a nuclear-powered submarine came as welcome news.

Dr. Lyon (left) and CDR W. R. Anderson (right) watching sonar aboard USS Nautilus *(SSN 571).*

The crew of *Nautilus* left the submarine as national heroes. They received a ticker-tape parade down Fifth Avenue in New York. Dr. Lyon accompanied them, and then returned to San Diego with two trunks full of data, information for analysis at NEL. Dr. Lyon's instruments had collected more data about the Arctic in an hour than had been gathered in years of exploration from the surface.

After these two *Nautilus* voyages, two conclusions became apparent: first, the ice pack was much thicker than previously thought (as much as 65 feet, not 10 to 15 feet), and second, ice keels projected down as far as 100 or 125 feet. While transiting under the ice canopy, *Nautilus'* fathometers also mapped the Arctic Ocean floor, revealing underwater mountain ranges that rose thousands of feet.

Dr. Lyon's most famous under-ice cruise occurred in March 1959, when he directed USS *Skate* during its first breaching of the ice at the Pole. Before the cruise, Dr. Lyon, along with other NEL scientists, developed the active sonar that permitted *Skate* to penetrate the ice pack and to surface through several feet of ice. In 96 hours submerged, the submarine covered 1830 miles and eventually surfaced near Greenland to within a few miles of where her inertial navigation system had placed her.



USS Skate *(SSN 578) surfaced at the North Pole, March 1959.*

Welcome home for Dr. Lyon after Nautilus *cruise. He is greeted by NEL Commander, CAPT John M. Phelps. NEL's Archie Walker is at left, and Technical Director, Dr. Franz N. D. Kurie, is at far left.*

Deep Submergence: *Trieste*

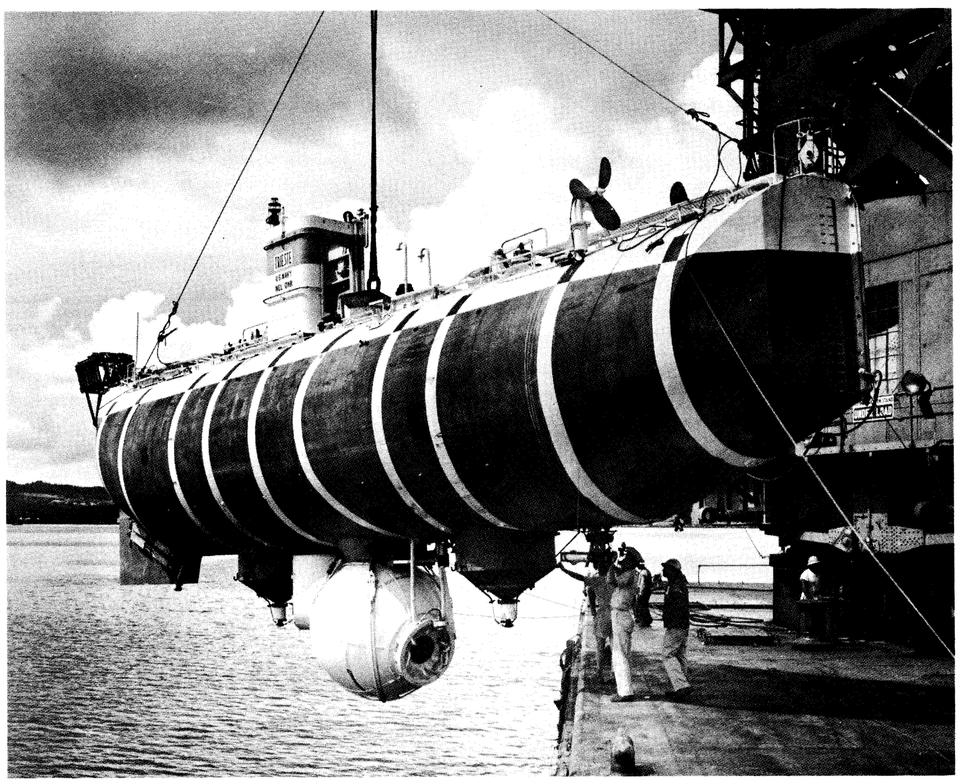
In addition to its arctic research, NEL took part in ocean studies in other parts of the world. Swiss oceanographer Auguste Picard believed that direct personal observation by scientists was necessary to develop adequate knowledge of the ocean floor and the water column. But when he began exploring the ocean floor in the 1930s, the only available technology was the tethered bathysphere or the diving bell, unsafe due to mechanical limitations. Dr. Picard obtained support from Swiss, Italian, and French Navy sources and built two tethered bathyscaphs in the 1940s and 1950s. Having had experience in free-flight in hot-air balloons, Dr. Picard, in 1953, designed and built a free-swimming undersea vehicle with a large float (like the balloon) supporting a manned pressure sphere (like the gondola) and called it *Trieste*. Built in Italy, *Trieste* was capable of deep (20,000 feet or deeper) submergence operations.

The Office of Naval Research (ONR) supported a series of Mediterranean dives of *Trieste*. ONR liked what it saw and bought *Trieste*, contracting with Picard to instruct U.S. Navy personnel in its operation. ONR gave *Trieste* to NEL to use with the laboratory's sonar and oceanographic research, since

San Diego enjoyed good year-round weather, nearby deep ocean, and ample support from fleet facilities. *Trieste* arrived at NEL in September 1958 and made its first U.S. Navy dive off San Diego on 20 December 1958.

Trieste was not simply a more capable submarine. Ordinary submarines of its era might dive to 200 or 300 feet; *Trieste* went to a world-record depth of 35,800 feet and withstood pressures of 16,000 psi. *Trieste* was 5 tons negatively buoyant, and its reserve buoyancy was provided by gasoline. The crew was limited to just two or three people, and the dive itself was limited to about 8 hours due to the capacity of the storage batteries and oxygen. *Trieste* was "fail-safe" in that any system failure triggered the release of 16 tons of ballast, which would cause her to rise to the surface.

Under NEL, *Trieste* made 78 dives between 1958 and 1963. NEL scientists used it for a broad range of experiments embracing geology, marine biology, and studies of the water column, as well as tests of NEL-designed transducers and other sonar instruments. (Further details on *Trieste* are given in the 1960s section.)

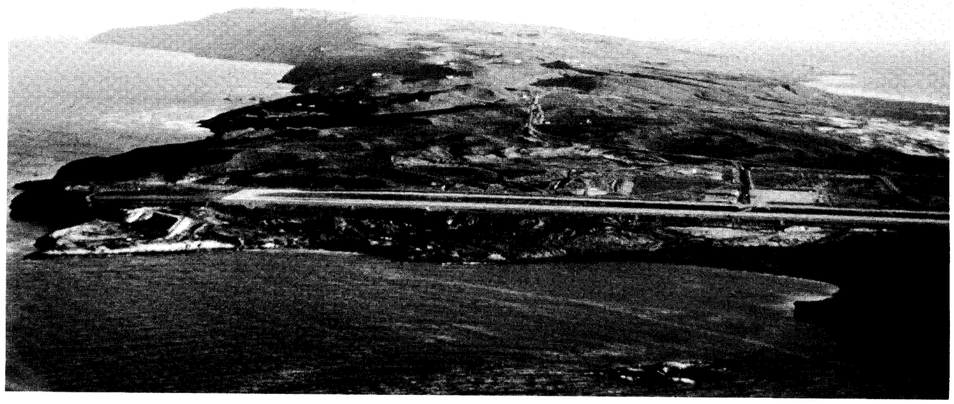


Trieste. *NEL used* Trieste *for broad-range experiments including geology, marine biology, and studies of the water column, as well as tests of NEL-designed transducers and other sonar instruments.*

Pasadena Management

As at San Diego, the management of Pasadena was shared by uniformed and civilian managers. In 1954, the Design and Production Department of NOTS Pasadena was merged into the Engineering Department at Inyokern and moved there. In 1955, the post office address and official name of the Station was changed from NOTS Inyokern to NOTS China Lake. Only the Underwater Ordnance Department remained at NOTS Pasadena.

Throughout the 1950s, NOTS Pasadena continued as an annex of China Lake and performed the major parts of such programs as torpedo research and development, underwater weapons testing and recovery operations, and the Polaris feasibility and testing program. As its work expanded throughout the decade, NOTS Pasadena grew to some 500 billets and took on the additional responsibilities of supervising range operations at sea in the same way that China Lake supervised weapons testing on its desert range.



San Clemente Island. Underwater test ranges off San Clemente Island were used for high-velocity, water-entry studies; large-scale underwater entry studies; and large-scale, underwater ballistics experiments. (1971 photo)

Pasadena Facilities

In 1951, NOTS Pasadena first began to use the Long Beach Test Range facilities (476 square miles of ocean) for air drops and surface firings. At the same time, NOTS Pasadena contracted with the Commandant, Eleventh Naval District (San Diego), to use the Navy's underwater test ranges at San Clemente Island. The San Clemente Island range continues to be used for high-velocity water-entry studies, large-scale underwater launch studies, and large-scale underwater ballistics experiments. The high cliffs and rapid drop-off of the ocean bottom allow underwater launches and air drops of weapon systems close to the shore. This capability simplifies coverage from many surveyed camera sites at different locations on the cliffs. San Clemente Island offers a combination of features including isolation from the public, accessibility for both the Navy laboratory and the Fleet, protected open ocean, climate, water depth, and available sites for data recording.

NOTS Pasadena: Advancing Torpedo Technology

Within less than a decade after its establishment, NOTS Pasadena became recognized for its knowledge and competence in applied research and component development of underwater weapons. In 1952, BuOrd assigned NOTS Pasadena general direction of aircraft-launched torpedoes and related accessories. Technical direction and design cognizance became terms of the day. This new responsibility added impetus to the trend toward development as the focus of activity, with research and testing oriented to support the development programs.

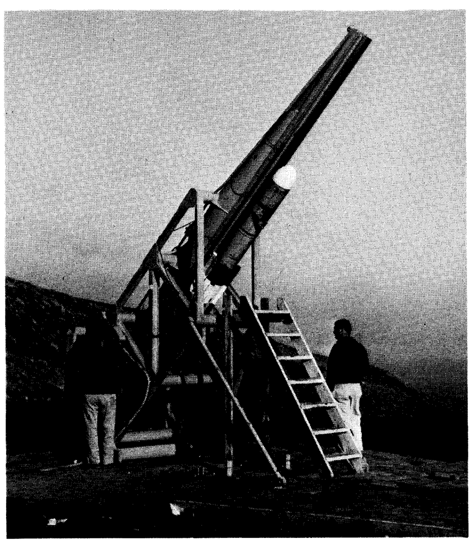
During this period, NOTS was assigned technical direction of projects such as the Mine Mk 24, Torpedo Mk 13 (as Petrel missile payloads), Torpedoes Mk 32, Mk 41, EX-8, Mk 43 Mods 0 and 1, and Mk 44.

Torpedo Mk 32

Even though the Korean conflict was primarily a land-based action, it brought increased activity to NOTS Pasadena. Torpedo work centered on the Mk 32, an acoustic homing torpedo that had been in experimental evaluation at Key West and had been shelved at the close of World War II. The responsibility of NOTS Underwater Ordnance Department was to reactivate, complete development, and carry the torpedo through to the point of fleet issue. Designed to operate below 100 feet at speeds to 11 knots, the Mk 32 was released to the Fleet in 1954.

Torpedo Mk 43 Mod 1

Developed by NOTS Pasadena and the Brush Development Company of Cleveland, Ohio, the Torpedo Mk 43 Mod 1 was the first lightweight, antisubmarine torpedo capable of being launched by helicopters, fixed-wing aircraft, and surface ships. Approximately 5000 of these torpedoes were produced from 1951 through 1959. This torpedo was withdrawn from fleet use after introduction of the Mk 44 torpedo.



Mk 43 Mod 1 torpedo at San Clemente Island, 1955.

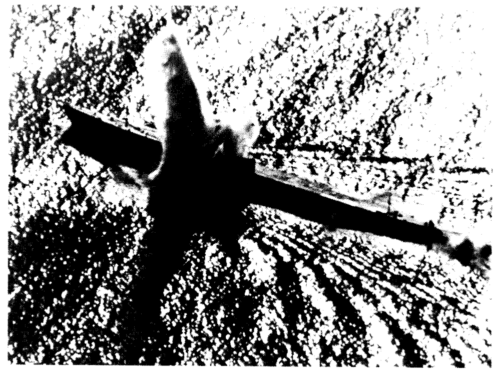
Torpedo Mk 44

The main work of NOTS Pasadena remained air-dropped torpedoes. But by the 1950s, the Navy no longer thought of lightweight torpedoes as primarily air-dropped ordnance to sink surface ships. The Soviet Union had a large fleet of submarines and practically no surface ships of note, so the orientation of lightweight torpedoes shifted toward ASW. Beginning in 1953, NOTS Pasadena and the General Electric Company of Pittsfield, Massachusetts, developed the electrically powered, acoustic homing Torpedo Mk 44. A distinctive feature of the Mk 44 was its active sonar, which enabled it to detect submarines as well as to home in on them once the target was localized. The Mk 44 went to the Fleet in 1958 and was initially deployed only from aircraft and surface ships. But late in the 1950s, NOTS Pasadena modified it to be used on helicopters and on the new thrown-ahead antisubmarine rocket (ASROC).

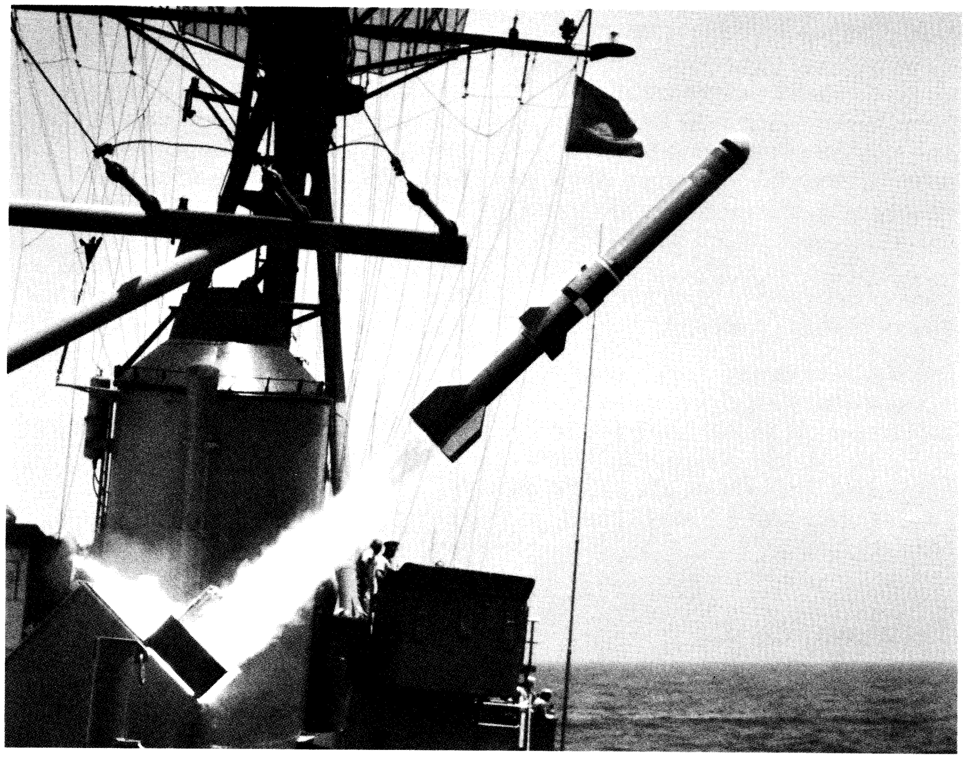
Antisubmarine Rocket (ASROC)

The success of Weapon A, a rocket-launched depth charge, paved the way for NOTS to develop a rocket-assisted torpedo, a quantum improvement in extending the power of ASW forces. Work on the Rocket Assisted Torpedo (RAT) began in the early 1950s and was proceeding when, in 1955, BuOrd asked its laboratories to assess the feasibility and desirability of firing a nuclear depth charge from ASW ships. NOTS did not want a weapon whose use would inflexibly escalate any conflict into nuclear war. Instead, it offered to develop a rocket-propelled weapon capable of either a nuclear depth charge or a lightweight acoustic homing torpedo, such as the Mk 44. BuOrd saw the advantages in such flexibility, and in 1956 began to sponsor work on the ASROC. NOTS Pasadena developed the systems, and NOTS China Lake built the rocket motor.

Successful "hit" of USS ex-Burrfish (SS 312) by ASROC-launched torpedo.



ASROC. A rocket-propelled weapon system, ASROC used a lightweight, acoustic homing torpedo or an alternate nuclear depth charge.



The ASROC's initial payload was a Mk 44 acoustic homing torpedo, and, in the summer of 1960, an ASROC-launched torpedo successfully "hit" the submarine USS ex-*Burrfish* (SS 312) at ranges of 2500 and then 4000 yards. The complete ASROC system consisted of a new sonar, a digital fire-control computer, an eight-cell launcher, and the ASROC rocket itself. The entire system, however much an evolution from previous NOTS work, established a number of "firsts." The rocket motor, for example, provided a unique variable thrust controller that allowed its range and course to be varied while in flight. In addition, the Mk 111 Fire Control Group was the first digital computer on a surface ship to control a major weapons system. The ASROC was installed on a broad range of cruisers, destroyers, and frigates. Subsequently, when the Mk 46 torpedo replaced the Mk 44, NOTS engineers developed a backfit program to allow the newer, more capable torpedo to be used with ASROC.

Polaris Launch System

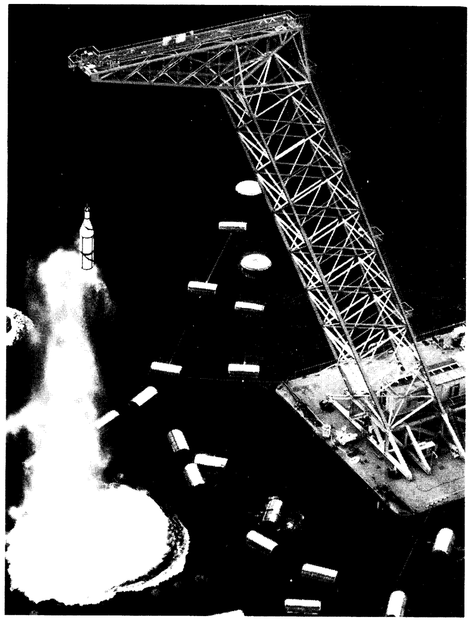
As an outgrowth of a 1955 Navy study entitled "Meeting the Threat of Surprise Attack," fleet ballistic missile systems, including submarine-launched missiles, were recommended to the Secretary of Defense, who authorized the development of this capability. CNO Admiral Arleigh Burke established the Special Project Office, administratively supported by BuOrd. Work began on the top priority Polaris missile in 1956. Four years later, the first Polaris submarine, USS *George Washington* (SSN 598), became operational.

At first, technical problems suggested that the Navy would never be able to launch guided missiles underwater. Rocket engines could not ignite underwater, and there was no other proven means of getting the missile to the surface. No information existed on how a missile launched underwater would function after being propelled through 50 or more feet of ocean. Would it remain on course? How would surface waves affect it? Could it be propelled high enough into the air for its engines to ignite? A project of this magnitude would have to be divided. As it turned out, Polaris research and development were divided into six main areas, each with a separate organization of Navy, government, contractor, and subcontractor personnel.

Lockheed was named prime contractor for the missile, but NOTS Pasadena worked mostly with Westinghouse, the contractor for the Polaris launcher and handling system. NOTS Pasadena had experience in underwater ballistics unequalled elsewhere in the Navy or in private industry. Thus, finding solutions for things such as launch depth, method of propelling the missile to the surface, safe underwater velocity for the missile as it reached the surface, maximum speed of the submarine, type of launch container, and the effect of surface waves on an underwater launch, all became part of NOTS Pasadena's role in Polaris development.

Operation Pop-Up began in 1957 in a section of Wilson Cove off San Clemente Island. NOTS engineers performed hundreds of test firings of redwood logs from an underwater launcher. Cameras were planted to photograph the motions of the dummy missiles in their progress through the water. By using varying amounts of air pressure, engineers studied how high out of the water each missile would pop.

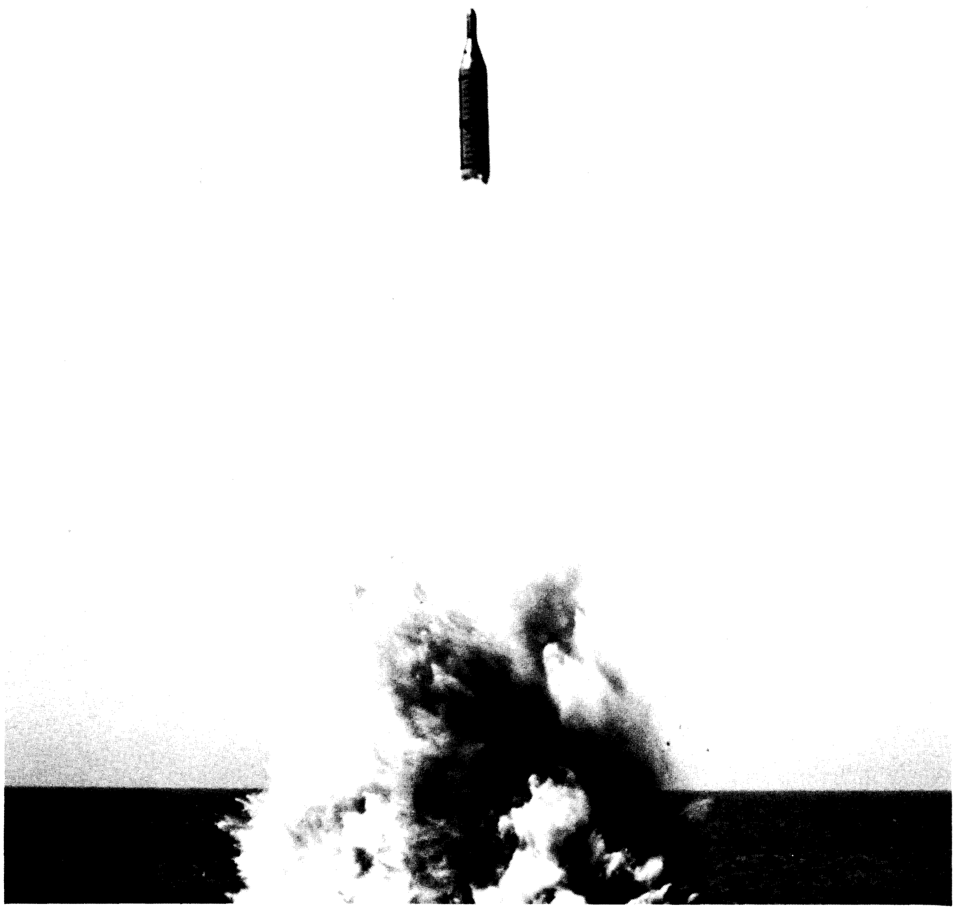
The next phase of tests traded the redwood logs for steel cylinders filled with concrete. These tests were then followed by the launching of concrete-filled boiler plates. (Boiler plates were probable outside structures of the Polaris filled with concrete rather than actual missile parts.) Finally, the actual missile structure was established and proof-tested. For these tests, a special crane, named "Fishhook," was built to catch the missile at the apogee of its unpowered flight. The crane supported the rigging and take-up mechanism that reeled in a cable attached to the missile. As the missile traveled upward through the water and into the air, the cable would reel in at the same speed as the missile's upward travel. Since the missile was unpowered, and "popped up" by force of the ejection mechanism, the cable could be controlled to stop and "catch" the missile just before it began to fall back to the water.



"Fishhook." The Fishhook crane was used to test the Polaris missile at San Clemente Island.

During much of this same time, simulated Polarises were being tested in the NOTS Hydroballistics Laboratory, a test facility in Pasadena that comprised an open-jet vertical water tunnel and a variable atmosphere tank (VAT). (NOTS' vertical water tunnel was one of only three such tunnels in existence; the other two were located in Minnesota and in Germany.) Under these laboratory conditions, 1/5-scale Polaris missiles were tested for flow characteristics and other hydrodynamic properties that could be applied to the full-scale underwater launchings.

This series of tests, from laboratory to Fishhook, was completed on schedule in 1959, just as USS *George Washington* (SSBN 598), the Navy's first Polaris submarine, was about to be commissioned.



Polaris launching during Operation Pop-Up off San Clemente Island.

Meanwhile at San Diego, NEL scientists and engineers were addressing an equally critical issue for the Navy's submarine-launched deterrent, that of missile and submarine guidance. A ballistic missile submarine cannot surface to verify its position (and set the guidance system of its missiles) via celestial navigation. The only solution was to adopt an existing system of inertial navigation and miniaturize the system to fit inside each Polaris missile. Thus the missile could be programmed to reach a target at a set distance from the point of launch.

On 4 April 1960, a Polaris was successfully fired underwater from the test launcher off San Clemente Island. A few months later, *George Washington* fired its first Polaris, and a new era in naval warfare began.